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COMPANY

BY P. N. NUNN

THE DEVELOPMENT OF THE ONTARIO POWER COMPANY

BY

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THE ONTARIO POWER CO.

OF NIAGARA FALLS

BIRD'S EYE VIEW OF NIAGARA FALL

VELOPMENTS ON CANADIAN SIDE.

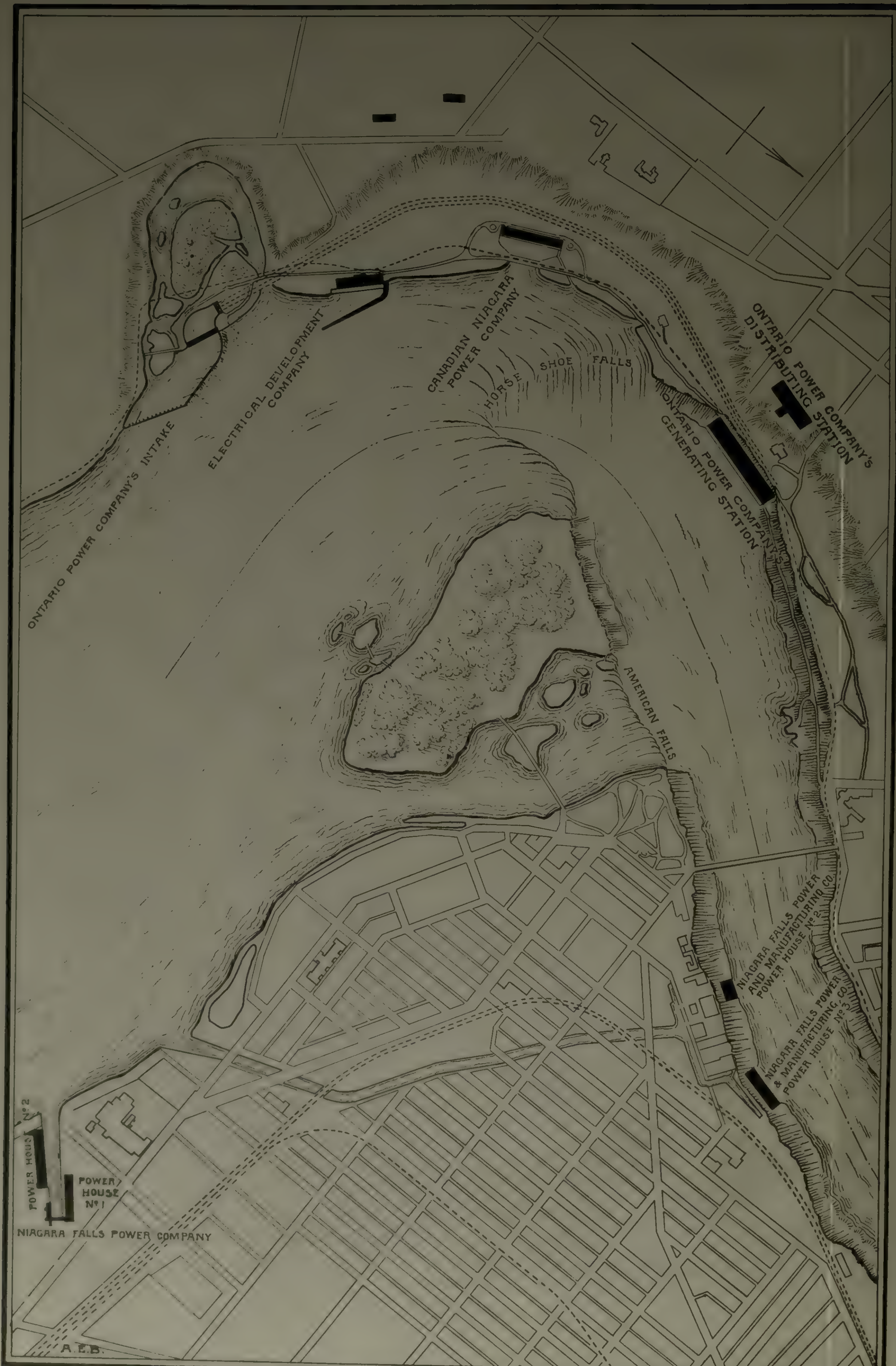
A paper presented at the 22d Annual Convention of the American Institute of Electrical Engineers, Asheville, N. C., June 19–23, 1905.

THE DEVELOPMENT OF THE ONTARIO POWER COMPANY.

BY P. N. NUNN.

THE development of electrical power at Niagara Falls has long attracted widespread attention and interest. Since the first installation upon the American side descriptions and discussions of its works and methods have been granted a conspicuous place in technical records and scientific press. It is not so well known, however, that four other developments, each larger than the pioneer, are now drawing or preparing to draw power from Niagara River. These differ so widely and so apparently as to type and character and express such differences of conception and method that it seems fitting at this time, when the largest is about to enter the active field, to present before the INSTITUTE, and through the channels of its PROCEEDINGS to the technical world, a brief description of a few features peculiar to this plant and a statement of the considerations which have led to so fundamental a departure from the type of construction hitherto characteristic of Niagara Falls.

Standing upon the upper steel-arch bridge and facing the Canadian falls, one may observe at the foot of the cliff forming the right-hand wall of the gorge, a long but unobtrusive building, its farther end obscured by spray from the great cataract. It is of modest though massive design and its colors almost blend with those of the overhanging cliff. This is the power-house or generating station of The Ontario Power Company. To the right, high above and behind the power-house, upon the bluff overlooking both gorge and cataract, may be seen another great structure, less massive but more ornate, which on account of its commanding position is by far the most prominent landmark of the Canadian side. This is the distributing station of the same company, from which the power generated below is controlled, measured and transmitted. Away to the left, around the bend of the river and hidden by the trees of Goat Island, are the walls, abutments and buildings of the intake and head-gates through which the water from Niagara River is diverted for use below. In the park between these extremes, seen just beyond Horse Shoe Falls, stands the power-house of The Canadian Niagara Power Company, while to the left another power-plant, that of The Electrical Development Company, is rapidly building.



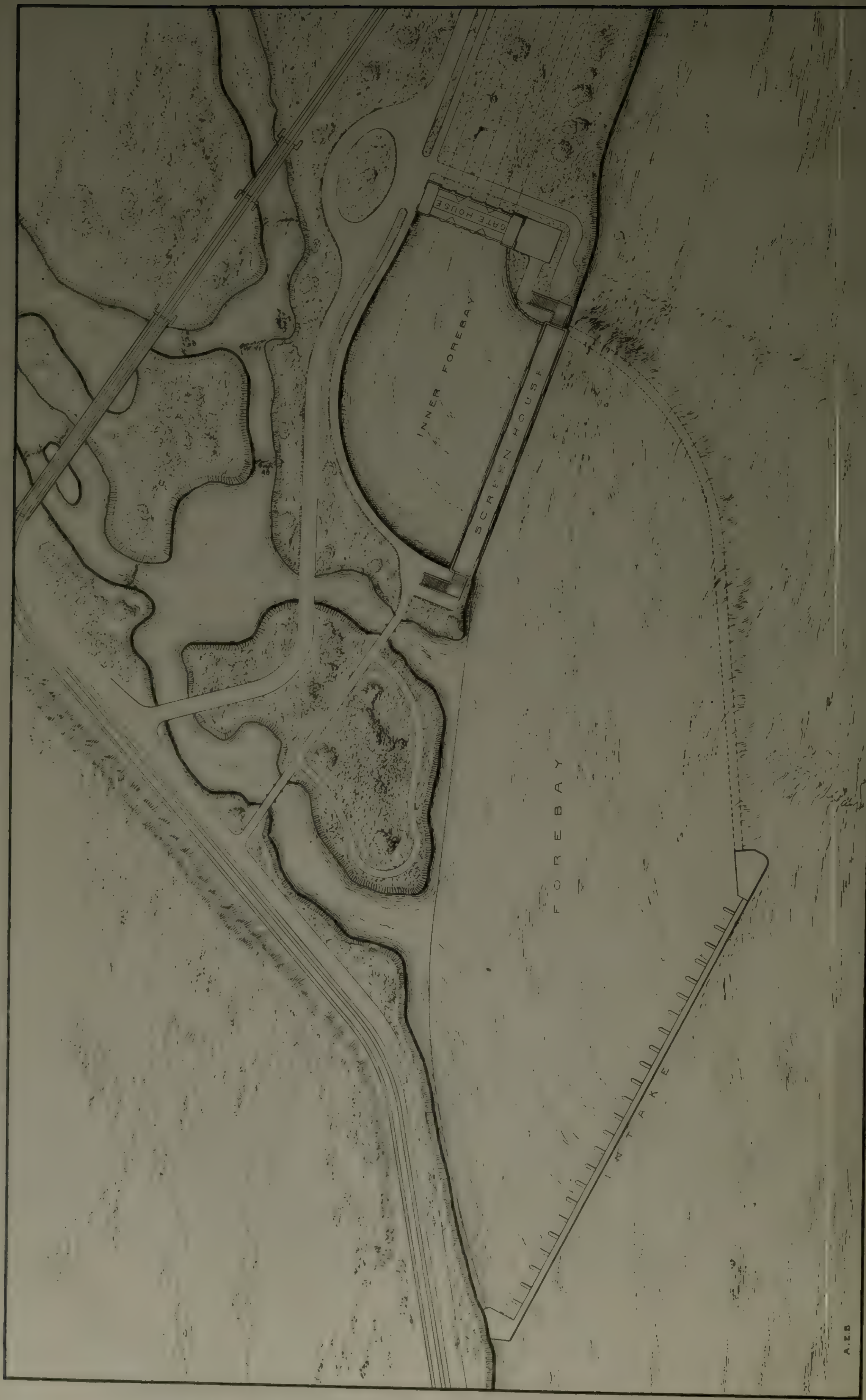
MAP OF NIAGARA FALLS SHOWING LOCATION OF POWER DEVELOPMENTS.

From the head-gates of the Ontario company three great steel-and-concrete tunnels or conduits beneath the surface of the park, will convey nearly 12 000 cubic feet of water per sec. to the top of the cliff above the power-house. Thence it will pass through 22 steel penstocks in shafts and tunnels down and out through the cliff to an equal number of horizontal turbines in the power-house below. From the generators the electrical cables turn back through tunnels to the 22 banks of switches, transformers and instruments of the distributing station above and to the transmission lines beyond, completing an equipment for more than 200 000 h.p.

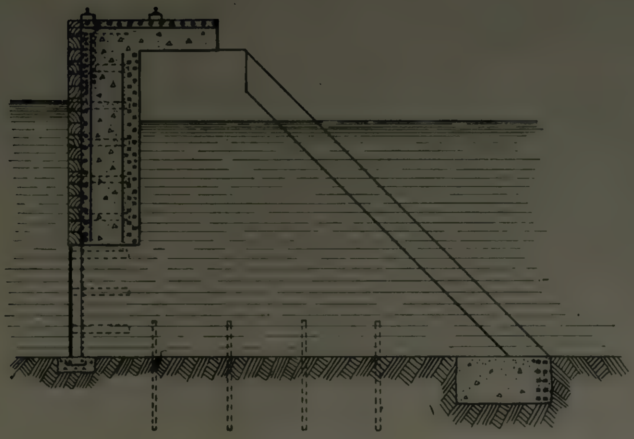
The intake-works for the entire 200 000 h.p. are now finished. One of the three main conduits is completed, while for the second and third, portals and head-works have been installed and a portion of the excavation made. Six of the 22 penstocks are already in place within their shafts and tunnels and two others are building, while the power-house is nearly prepared for the concomitant apparatus. The distributing station is completed for the switchboard of the entire 22 units, for the transformers of eight, and for other apparatus of 14. As to equipment, the coming month will witness one complete unit being operated, a second being tested, a third being installed, and a fourth being completed at the factories, with other units to follow as equipment of such size can be manufactured and installed.

The purposes and methods followed in the development of the pioneer plant and the environment and natural conditions at Niagara Falls have become so well known that interest in this younger development necessarily centers in its salient features or in those most likely to represent advance in engineering. The more important of these are the arrangement of intake-works, the design of main conduit and spillway, the horizontal-shaft units, the symmetry of arrangement, the centralization of control, and the protective isolation of apparatus.

The intake-works have been located and designed with especial reference to the ice difficulties which have been the limiting factor in the success of Niagara power. Cake ice in enormous quantities floats down for weeks at a time from the Great Lakes, and mush ice is formed in the turbulent rapids primarily by the freezing of spray and foam and secondarily by the disintegration of cake ice. To avoid the latter the intake is located in the smooth but swift water just above the rapids; to exclude the former the following features have been introduced: A long and tapering forebay protected at its entrance by the main intake terminates at its narrow, down-stream end in a deep spillway. Upon the river side it



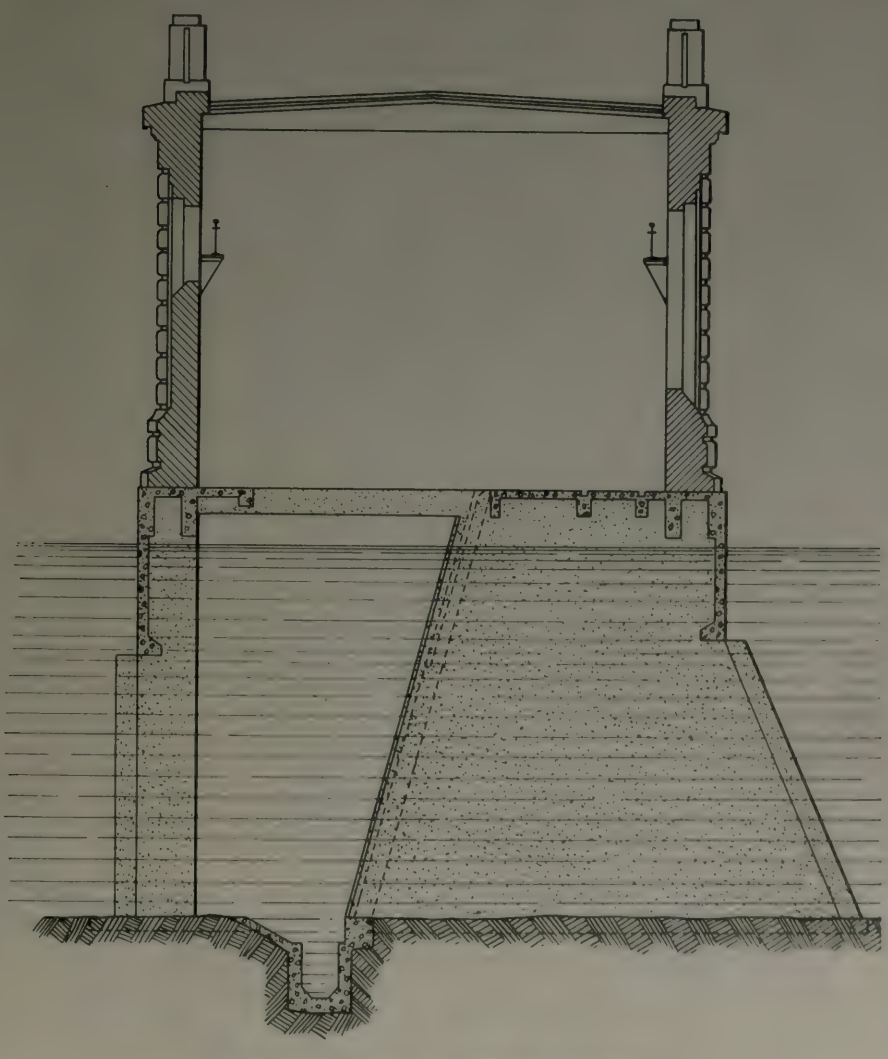
PLAN OF ONTARIO POWER COMPANY'S INTAKE WORKS.



SECTION THROUGH INTAKE.

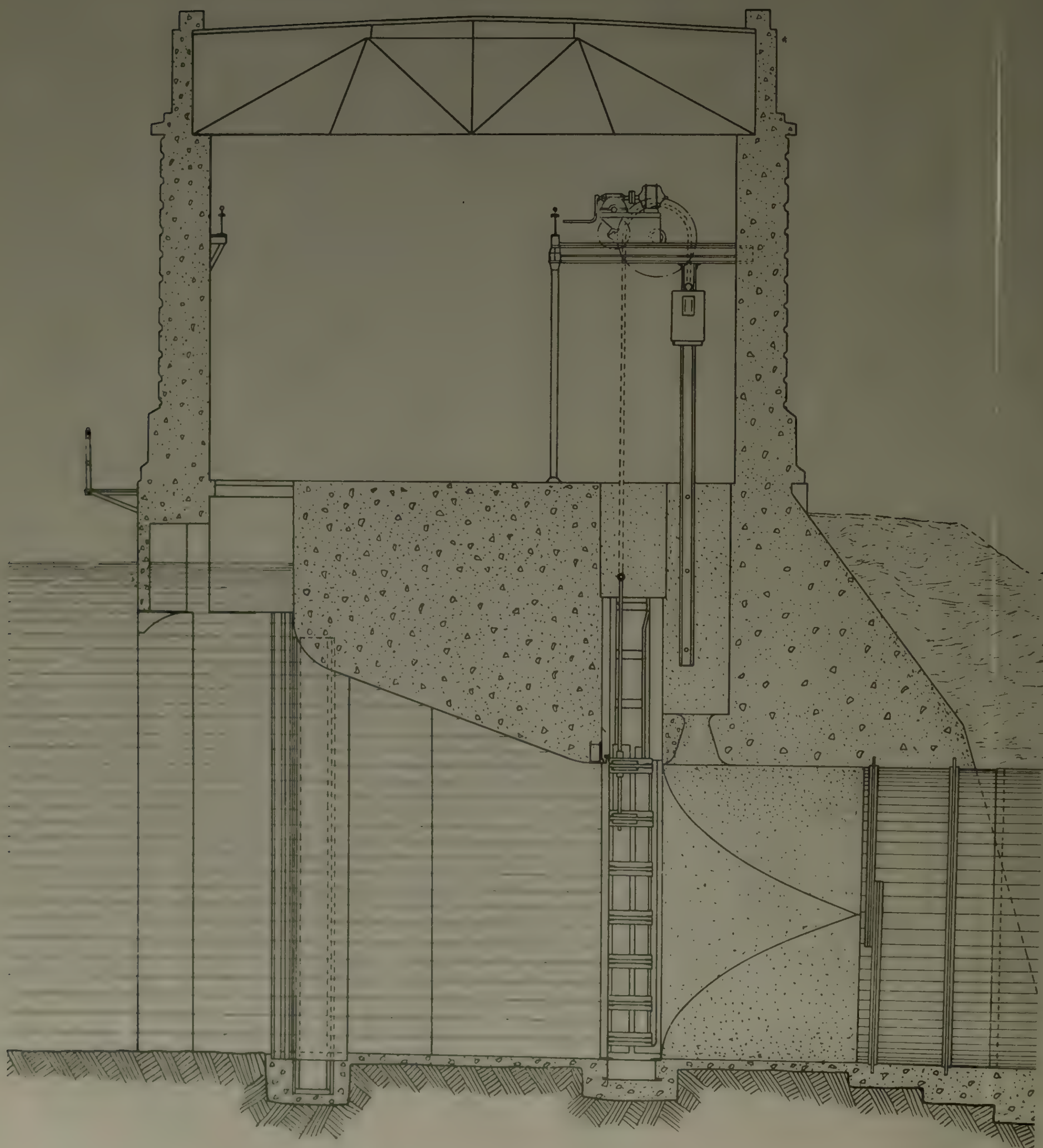
is enclosed by a submerged wall, while the other side adjacent to the spillway is occupied by the main screen structure leading to the inner bay and to the portals and head-gates of the three conduits.

The intake, nearly 600-ft. long, stretches across the inlet or bay at Dufferin Island almost parallel with the current in the river. Throughout its length a concrete curtain-wall extends down 9 ft. into the water, here 15-ft. deep, so that the gate openings beneath admit only deep water, and this at right angles to the swift exterior surface flow which, sweeping the full length of the curtain, carries the floating ice to the rapids beyond. At the main screen this operation is repeated. This



SECTION THROUGH SCREEN HOUSE.

EXTERIOR VIEW OF SCREEN HOUSE AND PROMENADE.



SECTION THROUGH GATE HOUSE.

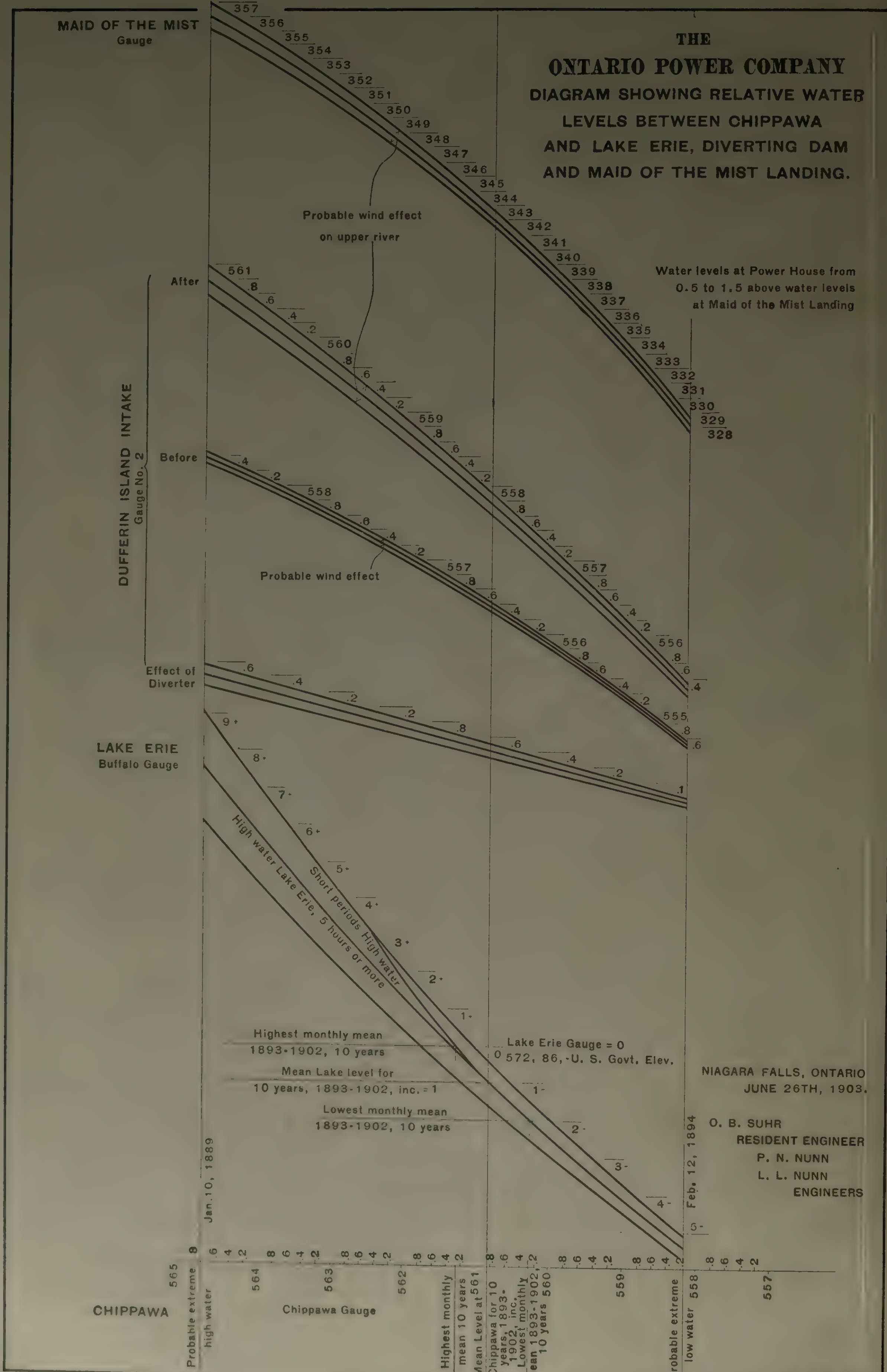
structure, 320-ft. long in 20 ft. of water, lies across the entrance to the inner bay and parallel with the direction of flow in the outer bay. Again a curtain, formed by the front wall of the enclosing superstructure, admits to the screens only deep water, here also at right angles, while it excludes ice with the surface currents maintained through the forebay by a voluminous spill of surplus water.

At the gate structure, where the water is 30 ft. in depth, the tapering portals leading to the electrically operated Stoney head-gates are protected with wide-mesh screens which are also enclosed and safeguarded by a curtain carried by the front wall of the gate-house. The bay in front of the curtain communicates with the river by an ample ice-run.

EXTERIOR VIEW OF GATE HOUSE.

Substantial concrete buildings shelter both head-gates and main screens. In each case an open canal between curtain and screen spills into a gravity ice-run emptying into the river. Both buildings are supplied with steam for heating and thawing from an underground boiler-plant situated in the common abutment.

Thus the water before entering the conduits must pass in succession three automatically selective steps, each excluding surface water and its floating ice, and two screens, each behind ice-runs in heated buildings containing live steam for emergencies. Serious trouble is not believed possible while these provisions are maintained with reasonable care.


THE
ONTARIO POWER COMPANY
DIAGRAM SHOWING RELATIVE WATER LEVELS BETWEEN CHIPPAWA AND LAKE ERIE, DIVERTING DAM AND MAID OF THE MIST LANDING.
MAID OF THE MIST Gauge
Probable wind effect on upper river
Water levels at Power House from 0.5 to 1.5 above water levels at Maid of the Mist Landing
DUFFERIN ISLAND INTAKE Gauge No. 2
After
Before
Probable wind effect
Effect of Diverter
LAKE ERIE Buffalo Gauge
High water Lake Erie, 5 hours or more
Short periods High water
Highest monthly mean 1893-1902, 10 years
Mean Lake level for 10 years, 1893-1902, inc. = 1
Lowest monthly mean 1893-1902, 10 years
Lake Erie Gauge = 0
572, 86, -U. S. Govt. Elev.
Jan. 10, 1889
Feb. 12, 1894
CHIPPAWA
Chippawa Gauge
Probable extreme high water
Highest monthly mean 10 years
Mean Level at 561
Chippawa for 10 years, 1893-1902, inc.
Lowest monthly mean 1893-1902, 10 years 560
Probable extreme low water
NIAGARA FALLS, ONTARIO
JUNE 26TH, 1903.
O. B. SUHR
RESIDENT ENGINEER
P. N. NUNN
L. L. NUNN
ENGINEERS
THE M.-N. WORKS, BUFFALO.

Screen frames are removable by an electric crane for cleaning and changing. On account of its location in the public park, the top of the long, narrow screen-house, approached at either end by broad steps and landings, is finished as a promenade. From this point of vantage one may have a superb view of the upper rapids. The islands and channels made in the course of this work give great opportunity to make this portion of the park most picturesque.

The height of the water in Niagara River, and therefore the volume here available, is dependent upon the surface elevation of Lake Erie, the erosion of the river bed, and such temporary causes as ice gorges, storms, etc. From calculations based upon comparative observations extending

MAIN CONDUIT DURING CONSTRUCTION.

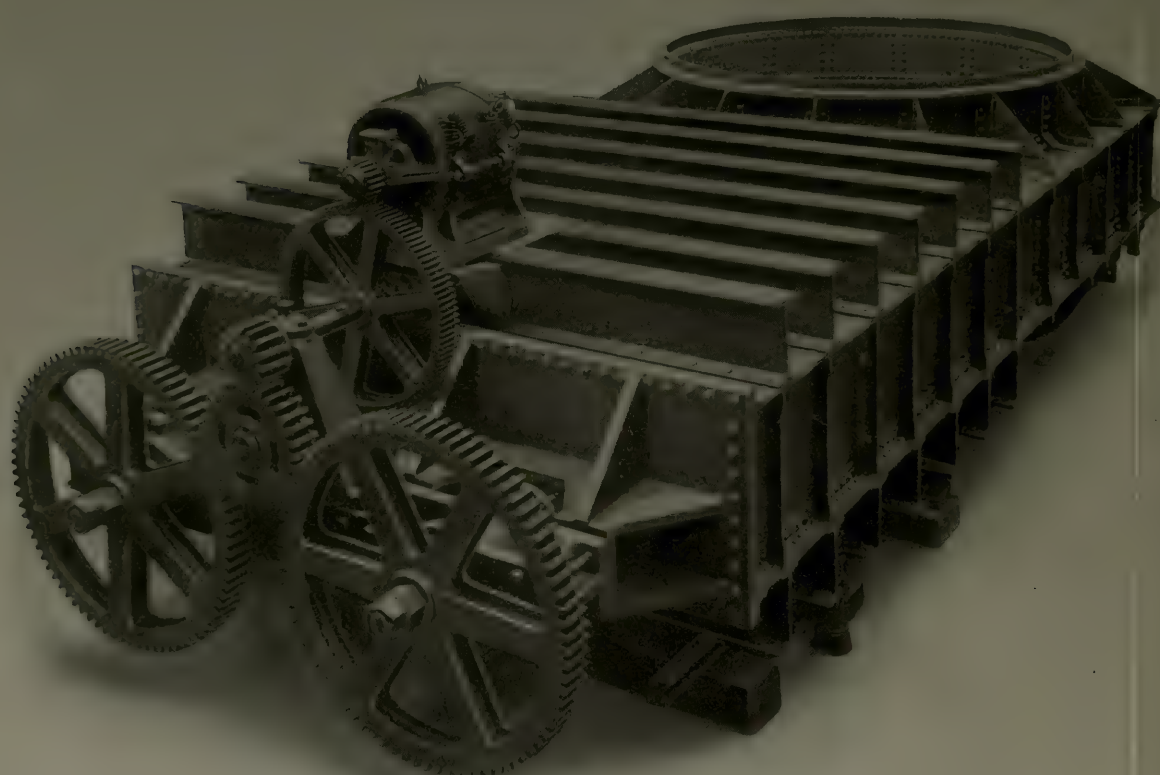
over a number of years and upon government reports of Lake Erie levels for nearly fifty years, the elevations of the intake have been so selected that at extreme low water and most adverse conditions a full supply of water should be secured.

The main conduits are of 0.5-in. riveted and reinforced steel imbedded

BIRD'S EYE VIEW SHOWING GENERATING AND DISTRIBUTING STATIONS COMPLETE FOR 200 000 HORSE POWER.

SECTION THROUGH GENERATING AND DISTRIBUTING STATIONS.

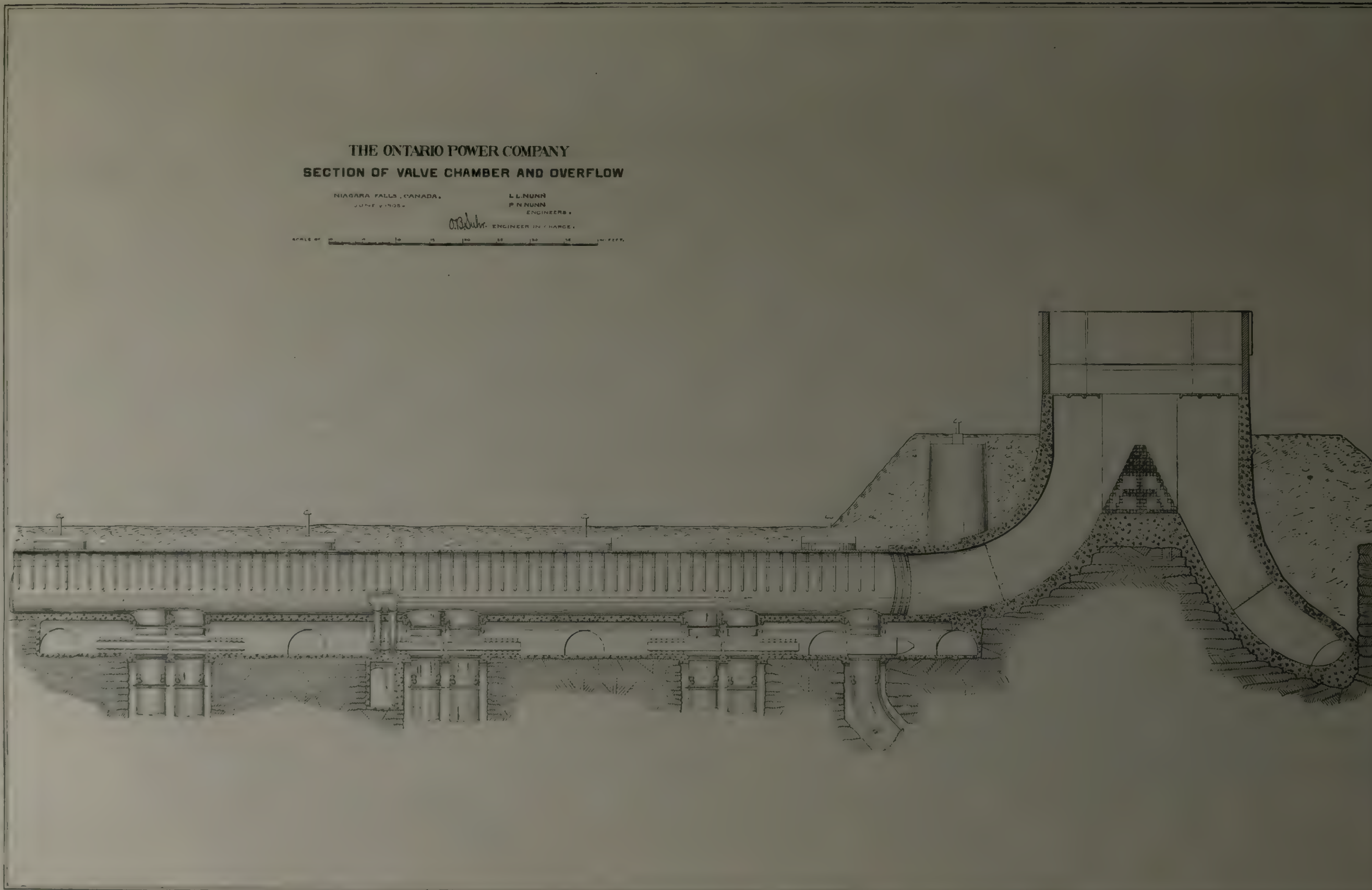
in concrete, 18 and 20 ft. in diameter, 6 500-ft. long, and are buried within the rock and soil of the public park. Through them the water flows at a velocity of approximately 15 ft. per sec. Just beneath the top of the cliff behind the power-house, within a long underground chamber, the arched roof of which supports the conduit above, 9-ft. diameter branches pass from the under side of the conduit through gate-valves and become the penstocks, each supplying water at 10 ft. per sec. to a single turbine. Each penstock has two expansion joints, a massive thrust anchorage in the power-house foundations, and an automatic relief-valve



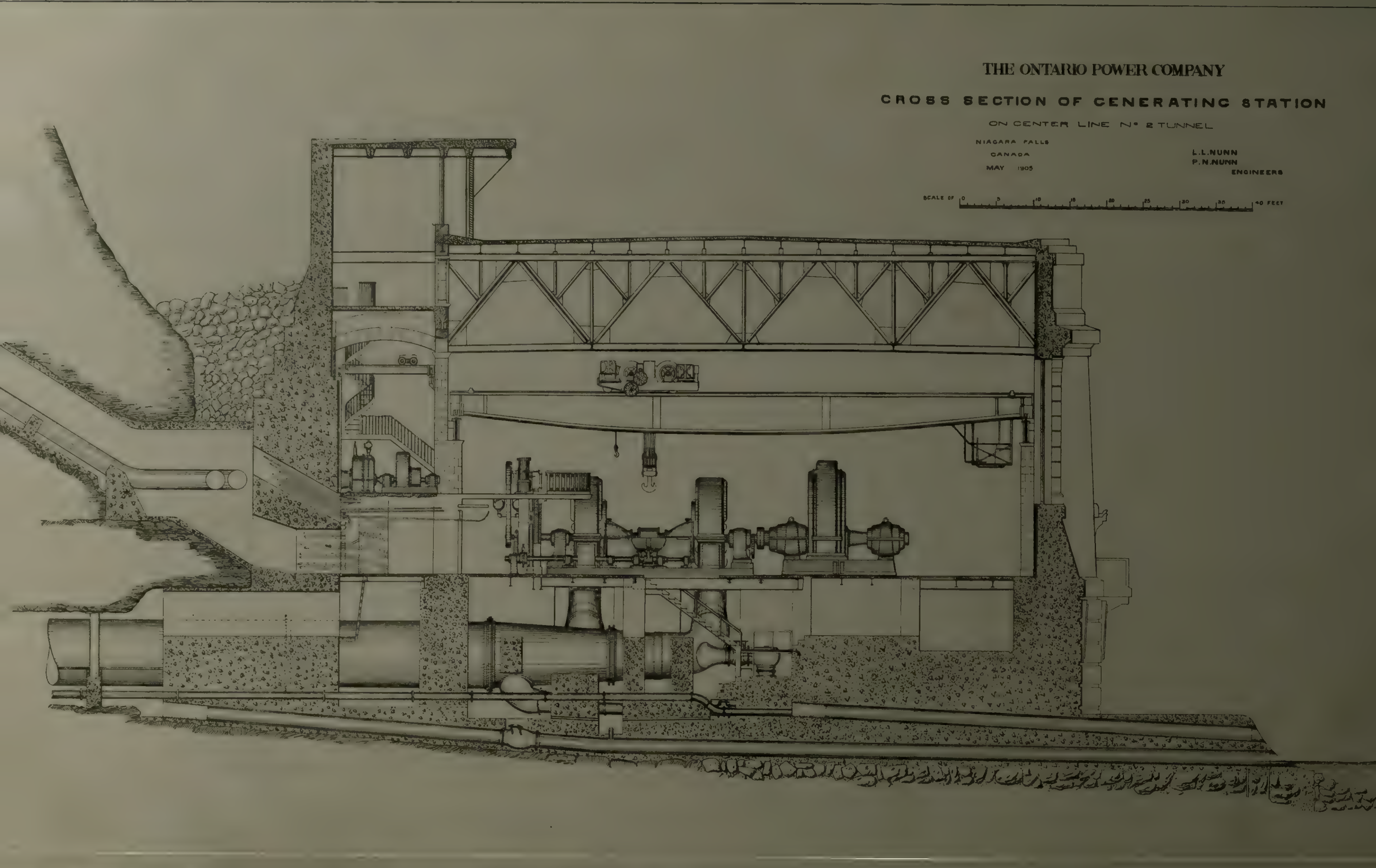
ELECTRICALLY OPERATED VALVE FOR NINE FEET DIAMETER PENSTOCK.

and a stone-catch discharging into the river. The 9-ft. valves are electrically operated under distant control from the power-house below, and are so constructed that all working parts may be removed for attention while the penstocks are in service.

The spillway at the end of the conduit, to prevent water-hammer in case of sudden loss of load, is little more than the enlarged and elevated end of the main conduit equipped with an enclosed weir and underground discharge. Its peculiar features are its adjustable weir and helical discharge-tunnel which, after a steep initial pitch in the taper from the weir, follows a uniform grade and symmetrical curve while circling about to



SECTION THROUGH VALVE CHAMBER AND HELICAL SPILLWAY.

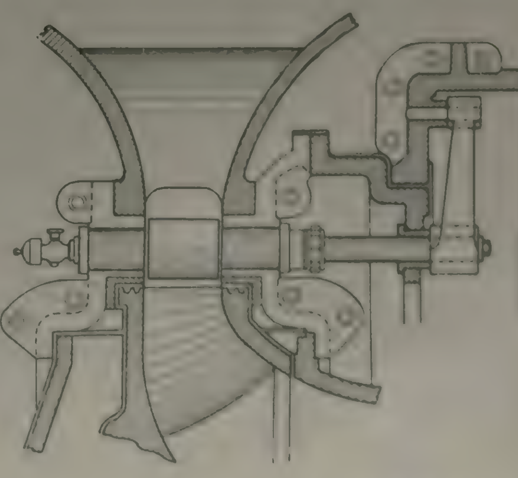


SECTION THROUGH GENERATING STATION.

reach the river, thus preserving a smooth unbroken water column of highest velocity and least expenditure of energy. The purpose here is to prevent erosion, restricted flow and excessive air-suction, the latter on account of the danger of formation of ice from spray under forced circulation of air.

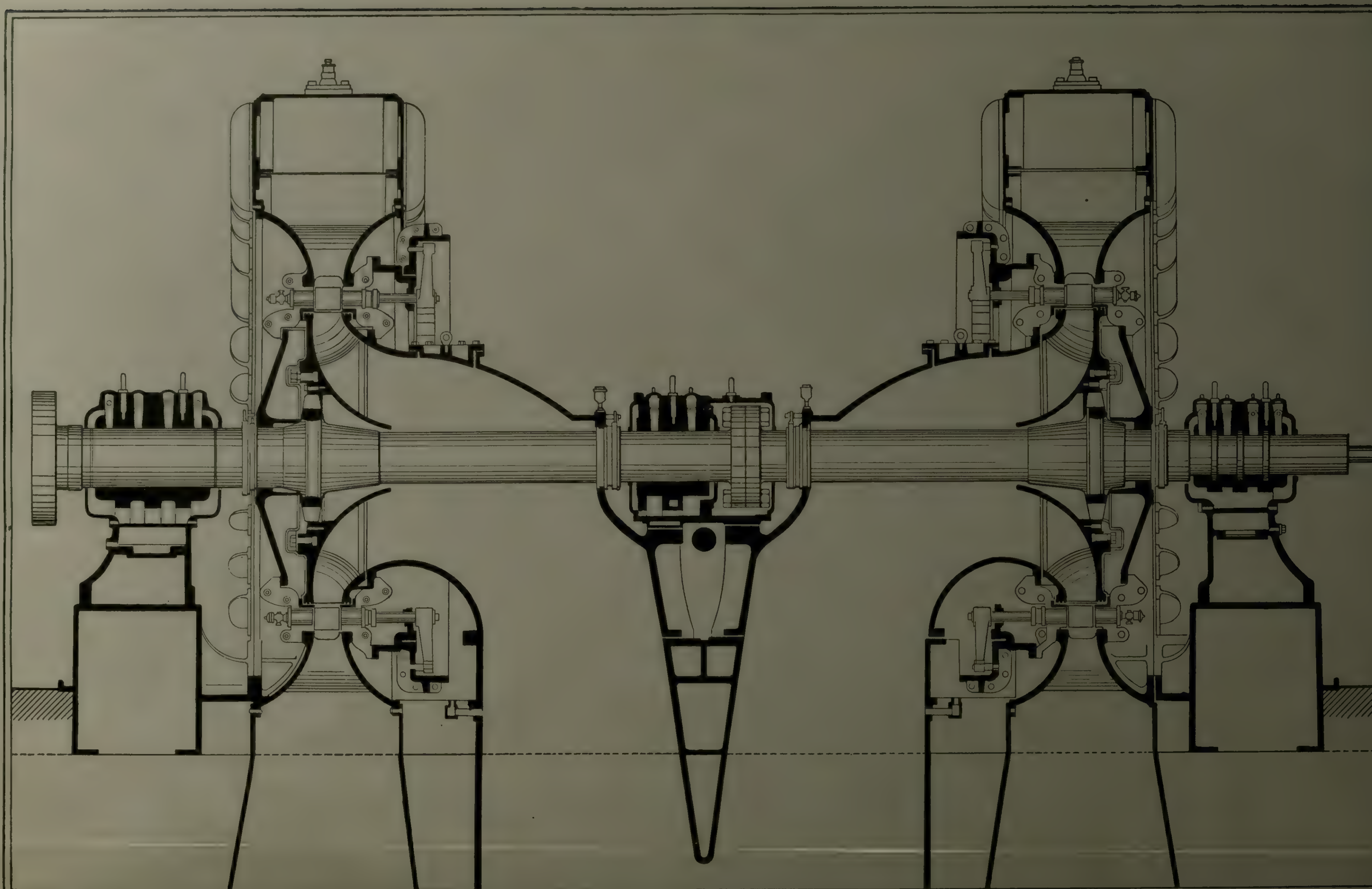
A TURBINE RUNNER.

The generators are of conventional horizontal-shaft type, three-phase, 25-cycle, and deliver 12 000 volts at 187.5 rev. per min. The turbines are of Francis or inward-flow type, double, central-discharge or balanced twin turbines designed to deliver 12 000 h.p. under 175-ft. head. Their shafts are 24-in. maximum diameter and each carries two 78-in. cast-steel runners of "normal" reaction. Housings are of reinforced steel plate, 16 ft. in diameter, spiral in elevation and rectangular in plan. Gates are of the wicket or paddle type, and the rotating guides forming them are carried by shafts which project through stuffing boxes to an external controlling mechanism, thus freeing the casings from the objectionable interior gate-rigging and leaving their approaches to the guides symmetrical and open. While the velocities in housings and draft-tubes are high, corresponding losses are avoided by nicely modulated changes of both velocity and direction and by symmetrical and liberal curves free from abrupt angles or obstructing projections.



OPERATING MECHANISM OF TURBINE GATE.

Of the 175-ft. head, 20 ft. is in the 10-ft. diameter draft-tubes, because the floor of the power-house has been elevated 26 ft. above mean water level to provide for the excessive variations to which the water in the gorge is



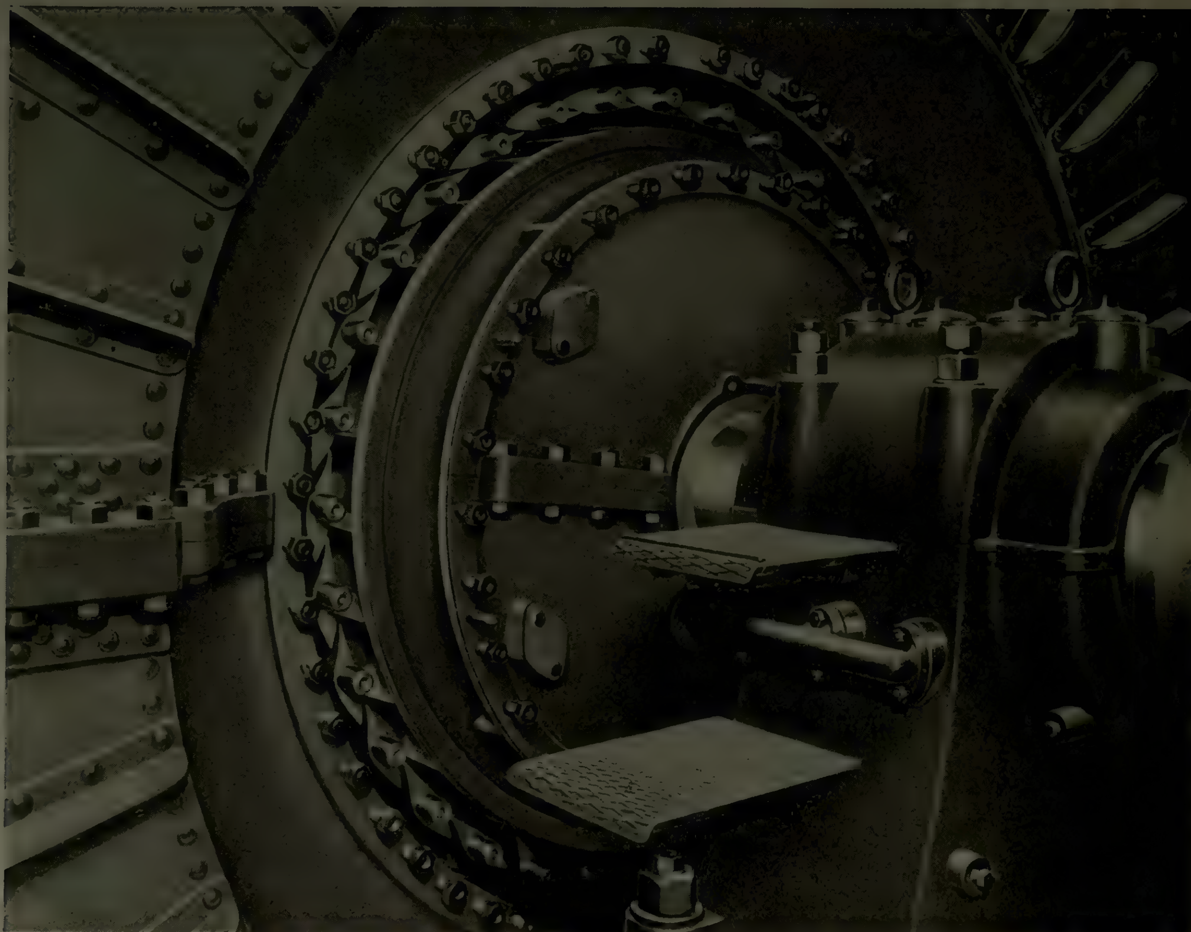
SECTIONAL DETAIL OF HORIZONTAL TURBINE.

subject. While bearings are self-oiling, all are equipped with water-cooling system, and for still greater insurance a piping system for the changing of oil has been so connected that in emergency it is instantly available for forced lubrication. Believing that disorders of bearings and journals, like those of people, are usually the culmination of gradually increasing ailment, each bearing is supplied with an automatic record-making thermometer providing the superintendent with a daily record, not only

EIGHTEEN FOOT DIAMETER CONDUIT SHOWING CONCRETE ENVELOPE.

of the temperature of the bearing but also of the temperament of the attendant as well.

Although entirely feasible to use the vertical-shaft turbine and although restricted space at the power-house requires greatest floor economy, nevertheless horizontal units are employed on account of their freedom from step-bearings, their higher efficiency, and their greater accessibility. While step-bearings in certain places are entirely successful, as long since proved by screw propellers and more recently by vertical steam turbines, yet at best they entail much auxiliary apparatus requiring especial care and frequent



SWIVEL GATE EXPOSED BY REMOVAL OF COVER RING.

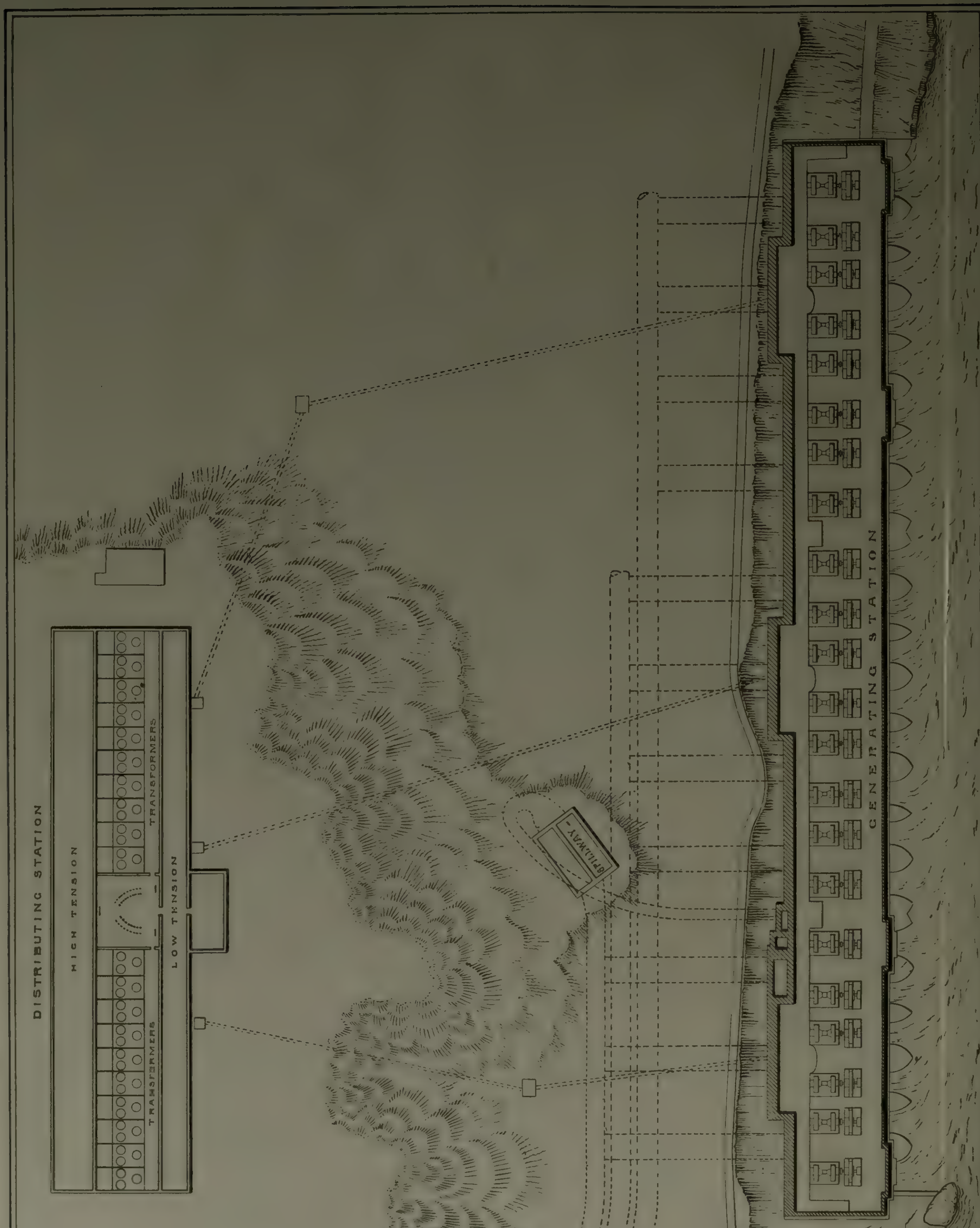
adjustment. With high-head turbines they have an uncertain record to be shunned wherever continuity of service is essential.

To reduce load upon the step-bearing, the vertical unit is usually of highest permissible speed. While efficiency at the generator is favored by this high speed, the effect upon the turbine is diametrically opposite and usually many times greater. This is because highest efficiency and durability seem to require "normal" reaction—a radial relative direction of bucket entry—and narrowly limited relative dimensions of runner. At such reaction peripheral velocity of runner (the components of which—diameter and rotation—are inversely proportional) is fixed by head. At such relative dimensions power is proportional to square of diameter; hence, inversely proportional to square of rotation. Increase of rotation, therefore, means disproportionately great decrease of power or abandonment of ideal reaction and relative dimensions. When carried to the extremes usual with vertical units, it results in inefficiently high reaction and reduced area of discharge, unfavorably abrupt changes of direction in buckets, and a wastefully distorted and overworked wheel. To such an extent is this

distortion carried to meet especial conditions that it is rare to find a high-head turbine possessing nearly the efficiency or durability possible if correctly proportioned. In the present case the speed selected permits almost exact "normal" reaction and ideal proportions without sacrifice at the generator.

Gratifying accessibility has been obtained by compact arrangement of generators and turbines with ample clearances and good light, upon the main floor of the station and in full sight not only of the immediate attendant but also of the chief operator from his post upon the gallery above. As explained, the entire gate-rigging is external, therefore accessible for lubrication, adjustment or repair. Excepting runners and gates, every moving part is in plain sight and, by the ready removal of a single ring, even the guides themselves are exposed for cleaning or replacing. This arrangement, in strong contrast with that of the vertical type with its several floors, intervening stairs and dark corners, will, it is believed, appeal to every power-house operator.

GENERATING AND DISTRIBUTING STATIONS DURING CONSTRUCTION.



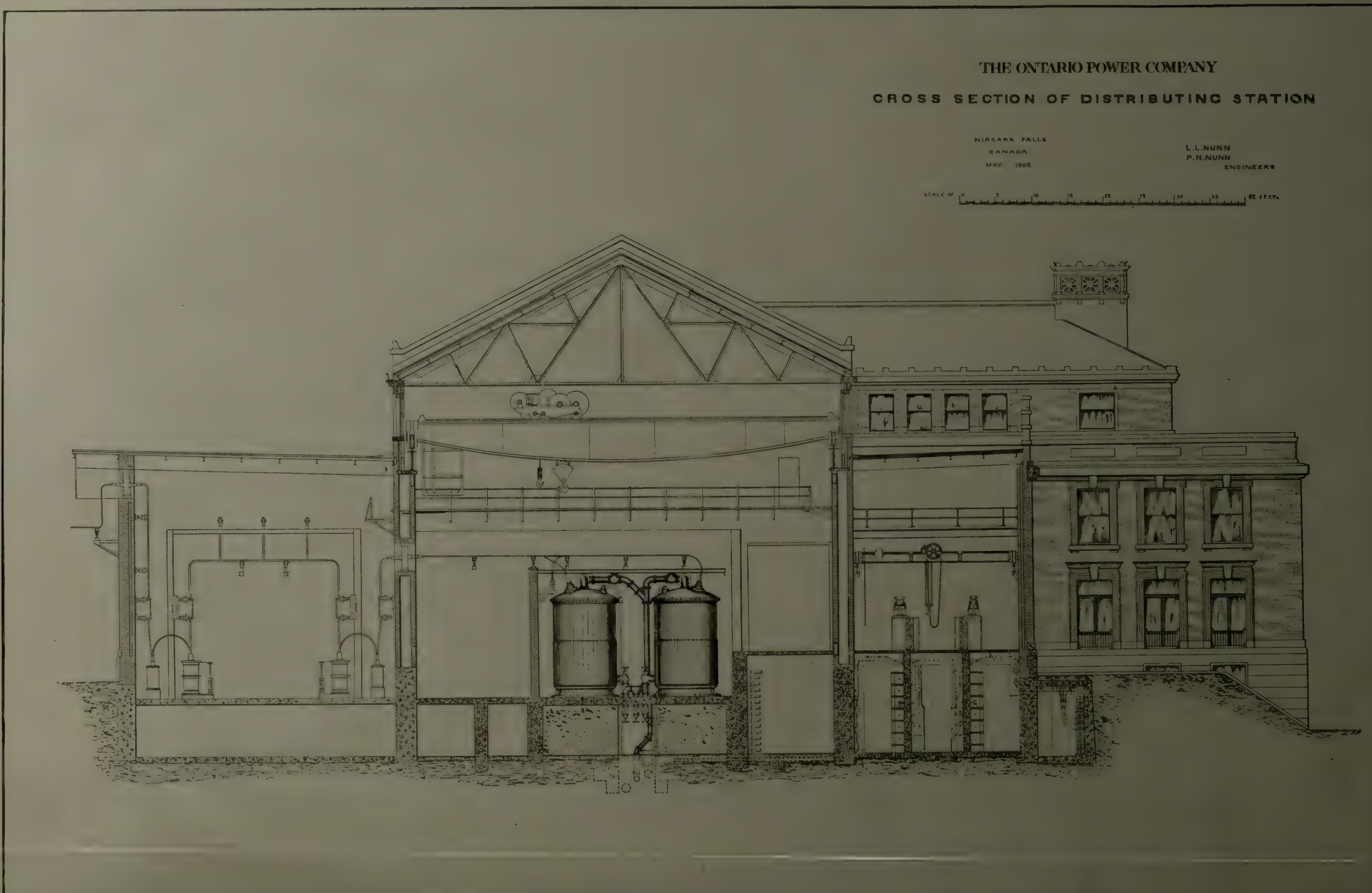
PLAN OF ELECTRICAL WORKS.

In the general arrangement of the works, symmetry and centralization of control are predominant characteristics. The generating and distributing stations are parallel and nearly 600-ft. apart with 260-ft. difference in elevation. On account of limited space the generating station is but 76-ft. wide, though when completed it will be nearly 1 000-ft. long. Down the center of this building, side by side in a single row, stand the generating units with turbines next their source of supply. The space between them and the rear wall is occupied by a gallery upon which stands the row of oil-pressure governors, each almost over the end bearing of its turbine.

The distributing station, wider and shorter than the power-house, is divided into three longitudinal bays or five main sections. The narrow front bay contains the switches, bus-bars, etc., at generator pressure; the wider rear bay contains those at transmission pressure. Between these stretches the main middle bay divided transversely by a three-floor switchboard-section into two long transformer-rooms. The projecting central section provides space for the operating offices. Along the center of these two rooms the transformers stand in groups of three corresponding in position and capacity to their respective generators. Thus similar apparatus is arranged in rows parallel one with another and with the generating units.

At the generating station three inclined cable-tunnels, one already built, carrying clay ducts, begin at the rear wall beneath the gallery and extend up through the cliff and, as standard subway, on to the distributing station. The main cables, except as diverted by these tunnels, follow the shortest and most direct routes from generators to transformers. They do not converge for the accommodation of switchboard at one or more centers where congestion prevents separation or adequate insulation, and in many installations causes the most disastrous accidents. On the contrary they are laid quite regardless of switchboard, the switches and instrument transformers of which are then placed as required by the cables.

Unit values, corresponding to the generators in capacity and position, are maintained throughout. Thus each generating unit has its individual cables, switches and switchboard, section of bus-bars, transformers, interrupters, and high-pressure switches complete to the transmission, enabling independent operation as an isolated power-plant or, through the selector switches and duplicate sectional bus-bars, the operation of all units in any combination of groups as readily and perfectly as their operation in parallel. To this end a unit length of distributing station of similar



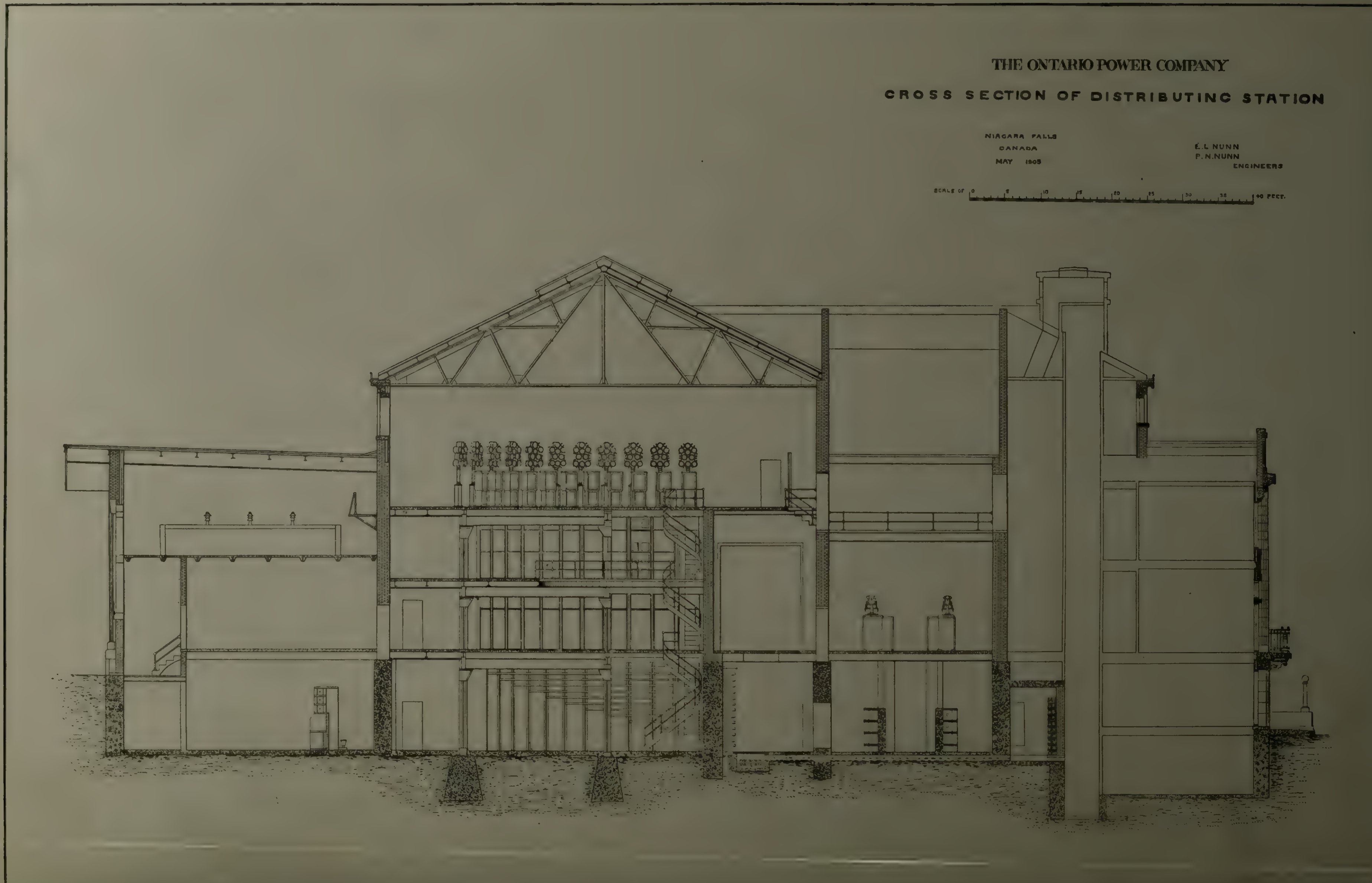
SECTION THROUGH TRANSFORMER ROOM.

relative position is devoted to the circuit and apparatus corresponding to each generator.

From the above it may be seen that the arrangement is in parallel courses; that like apparatus is arranged in rows or courses parallel with the long axis of the generating and distributing stations; that the main circuits and the unlike apparatus performing the successive functions of these circuits form 22 courses transverse to the same, and that the courses of the two directions form, as it were, a rectangular or checker-board figure covering an area nearly 1 000-ft. square. The arrangement of these courses in logical sequence provides the short and direct route for the main cables previously mentioned. Such symmetry of arrangement, while difficult to attain in a crowded plant or at points of congestion, is of marked value in emergency, especially in a plant of many units, and becomes vital when the units are of such dimensions that the accidental crippling of one costs the output of many smaller plants.

Where the cable tunnels commence, the power-house and gallery are widened toward the cliff. Immediately above the tunnel entrance are the main generator switches, and on one side the duplicate turbine-driven exciters and their governors, and on the other the motor-actuated main field rheostats. In front of the switches are a few panels of switchboard carrying exciter rheostats and switches, controls for actuating penstock valves, and the necessary circuits and apparatus for a limited local distribution. Relief valves and small drainage-pumps are the only operating machinery beneath the main floor, while upon it, in addition to the generating units, there are only duplicate electrically driven pumps supplying the storage tank and transformer cooling coils at the distributing station. For air circulation and ventilation and to avoid dampness from spray as well as to insure cool generators in hot weather, a cold air supply to each generator is provided from a sub-floor chamber communicating with external shafts and heated air escapes through large roof ventilators.

At the distributing station the low-pressure bay contains upon the main floor the 12 000-volt automatic oil circuit-breakers in double column and, in the chamber beneath, only the sectional duplicate bus-bars and their immediate connections. In the transformer-rooms the transformers stand in pits six feet below main floor level, and parallel with them adjacent to the high-pressure bay are corresponding pits for static interrupters or other protective apparatus. Beneath both and between their foundations are accommodated the several systems of piping for water, oil and drainage and the main cable-ways to the transformers above. Each transformer is



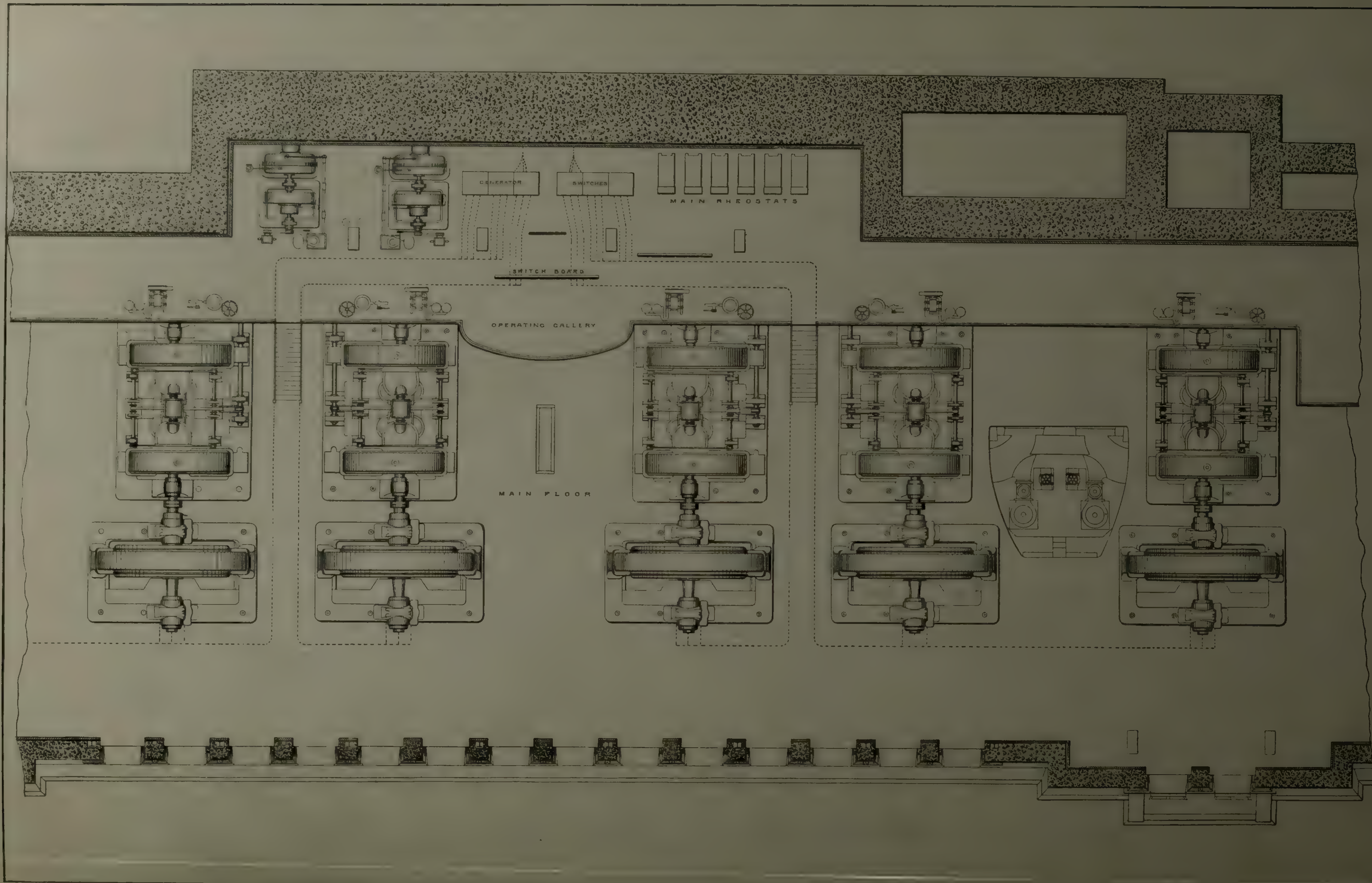
SECTION THROUGH CONTROL CHAMBER.

fitted with a record-making thermometer giving the continuous history of internal economy.

The switchboard section occupying the center of the distributing station has four floors of which the basement serves as a center for the piping systems and gives room for conduits and cableways for wiring. On the main and the mezzanine or gallery floors, marble slabs carry record-making and integrating instruments, terminal boards with fuses for the control cables, and other adjuncts of the switchboard above. Upon the upper floor is the switchboard and control chamber, and here instrument-stands and control-pedestals supplant both the conventional marble slabs and the later bench-board. Each of the 22 instrument-stands, which are arranged approximately in a semicircle about a central point, corresponds to a definite unit, carries nine indicating instruments and faces its twelve-point control pedestal. Doors upon the four sides lead to balconies in the four other divisions of the building of which this room is the center; those at the sides to balconies extending the full length of the transformer-rooms.

Centralization of responsibility and authority, at defined points within the immediate personal care of a minimum number of chief operators, is, next to simplicity of arrangement, the prime requisite of efficiency of organization and of economy of operation. It is frequently possible so to arrange small plants of a few units as to centralize at a single operator, but with a plant of this scope that result is manifestly impossible. Two alternatives are then open: the division of the plant into several parts, each about its subcenter constituting a complete plant in itself and the whole dependent upon successful coöperation for unity of result; or classification and centralization of responsibility according to kind. In this case the latter has been adopted, and notwithstanding that the number of units and aggregate of power involved have opposed high merit in this respect, a promising result has been obtained.

The concentration within a single room of all instruments and control — the brain of electrical operation — provides the operator in a quiet and secluded place both full information, and perfect control of every electrical circuit and situation of the system and enables him to stop, start, regulate or synchronize each unit; to throw its output through its transformers to its transmission as if from a complete isolated plant or to throw it upon either bus-bar while supplying its transformers from the same or the other bus-bar. The location of this room high up at the geometrical center of the distributing station places the operator at a point of vantage surrounded by four classes of apparatus. Thus located he may with few



PLAN OF GENERATING STATION, UNITS 2 TO 6.

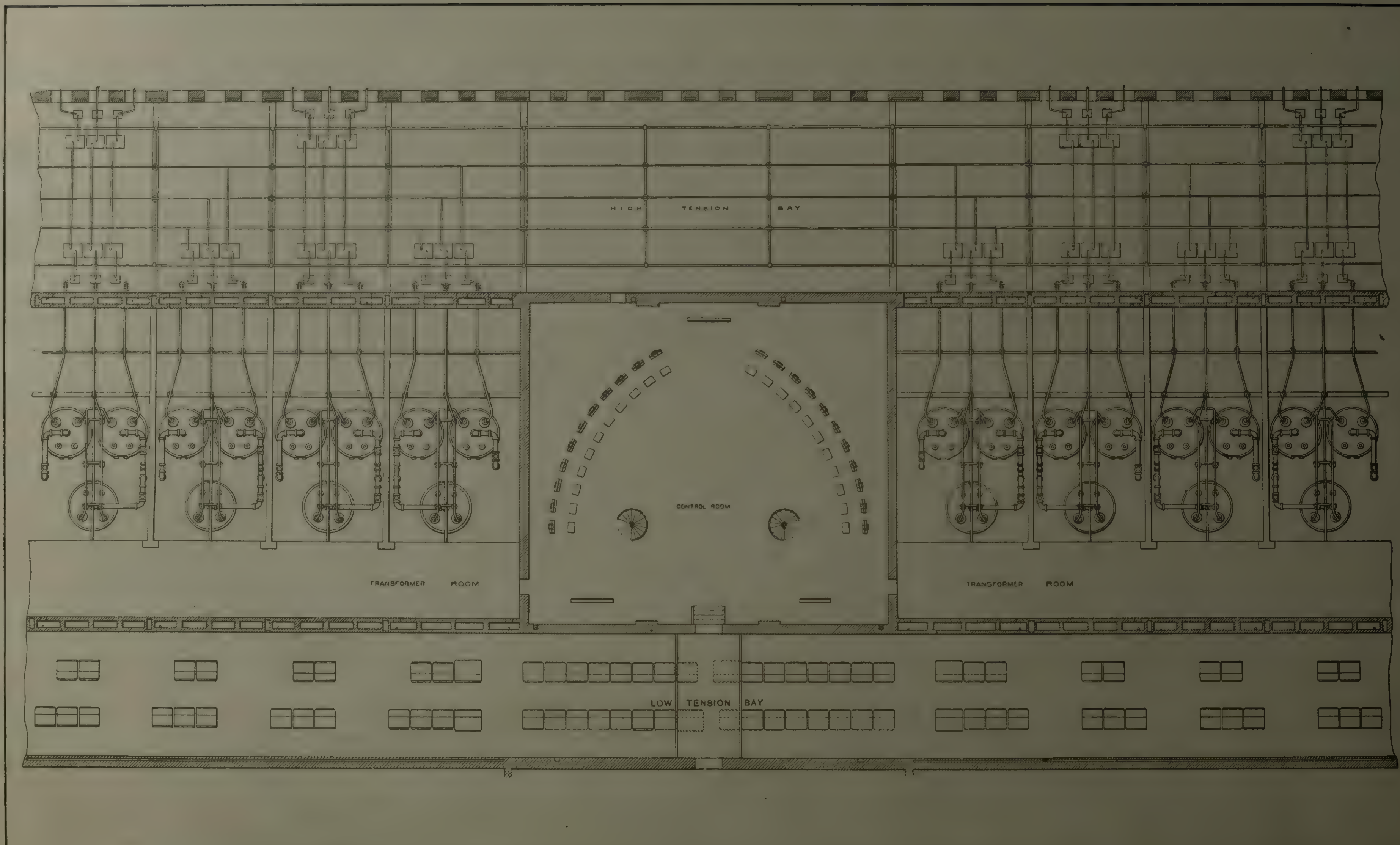
steps survey his entire field; look down upon switches, bus-bars and arresters of the high-tension; see at a glance every low-pressure switch; or watch trouble in either transformer-room.

At the generating station the corresponding vantage-point is the gallery, where on one side the operator has the motor-driven rheostats and a few paces distant the commutators and governors of the exciters, and on the other side in plain sight the row of main governors with their adjuncts; while from the little switchboard before him he has electrical control of penstock gates and, when necessary, manual control of turbine speeds, exciter pressure and field charge. Moreover from this position he can see all generators and turbines, and, by signal at least, can direct his assistants; little, in fact, is likely to call him to the main floor unless it be an occasional refractory journal or collector brush.

In accomplishing the centralization of switchboard simultaneously with the broad and symmetrical distribution of main circuits and switches already described, distant electrical measurement and control have necessarily been employed to an unusual extent. Pressure and current transformers, essential to the many instruments and relays beyond those necessary at generating station and high-pressure room, are mounted in the bus-bar chamber. The innumerable and long conductors, necessary to extend over the intervening distance from those to the many instruments of the switchboard and to convey back the power from relays and control buttons to automatic switches, have been gathered into substantial cables and laid in metal conduit.

The basement of the central bay along its low-pressure side forms a wiring chamber supporting a railway track upon the main floor above. Through this wiring chamber transverse to the general direction of the main cables and opening at its center into the control section, these cables and those for both continuous and alternating current local service are carried into the basement beneath the control section and, rising through the recording floors, end at terminal boards below their respective instruments and relays. Carried thus far, distant control has been still further applied by the use of motor-driven rheostats for both generators and exciters, electrically operated circuit-breakers for field circuits, and speed controllers for governors whereby, as previously mentioned, turbines may be started, stopped or regulated from the control chamber as well as from the gallery at the generating station.

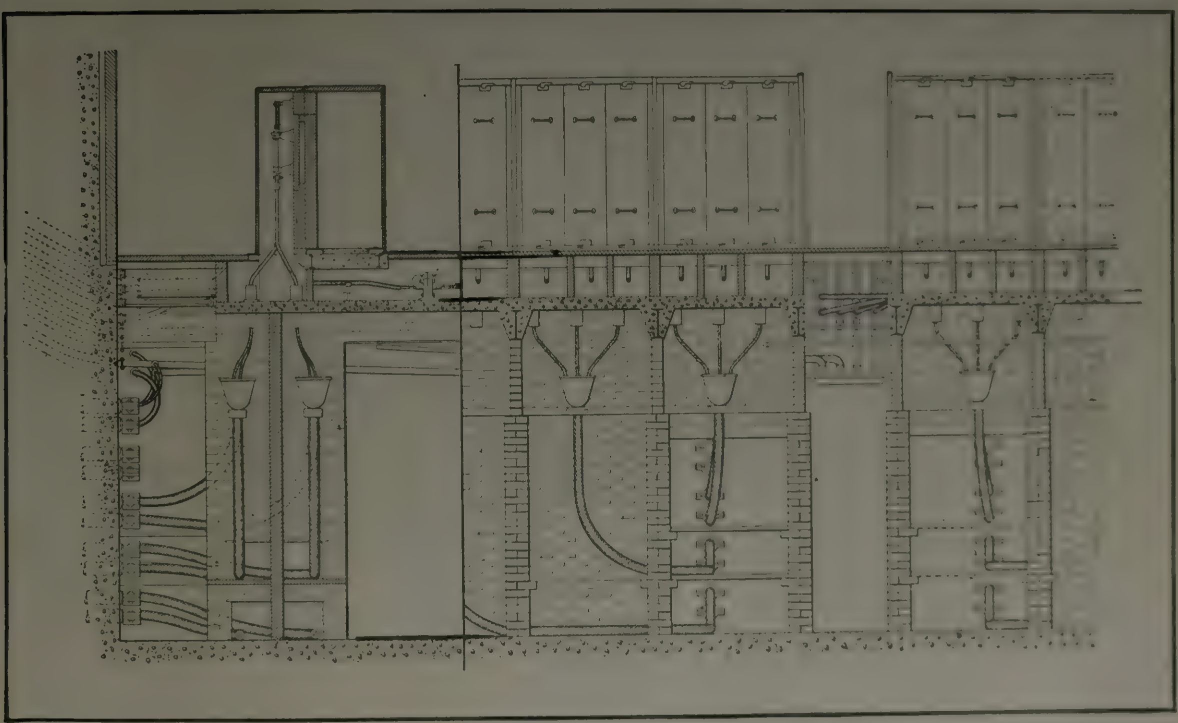
The isolation of electrical apparatus and conductors by incombustible walls or barriers against spread of oil or arcs, for protection from fire and from each other, is of importance proportional to the power and invest-



PLAN OF CENTRAL PORTION OF DISTRIBUTING STATION.

ment involved. Neglect of this precaution has caused many of the most disastrous electrical accidents and has recently taught several bitter lessons. Some rather extreme measures here taken for its more complete application may be of interest. The five sections or rooms, heretofore mentioned, forming the distributing station, are of concrete-and-steel fire-proof construction, separated by full-height masonry walls with intervening air-spaces. No windows and but few doorways (these latter protected by fire-proof doors usually closed) penetrate these walls.

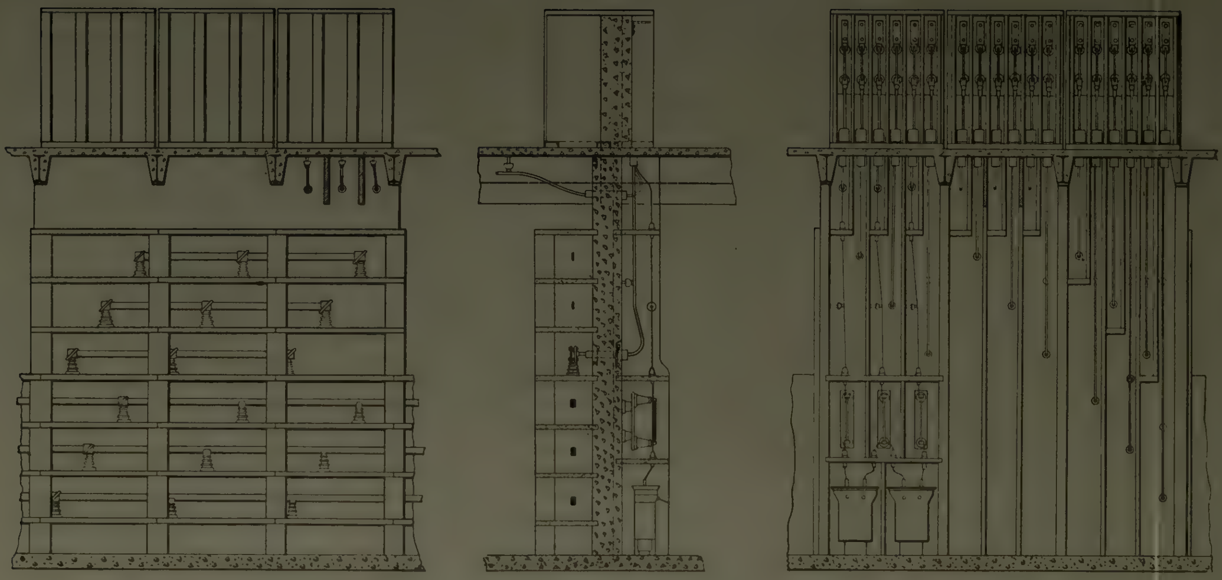
The transformer pits already mentioned, each containing a bank of three transformers, are isolated and extended to a height of 23 ft. by masonry fire-walls. Each individual transformer is in a boiler-iron casing



CABLE BELL COMPARTMENTS AND BARRIERS.

designed to withstand 150 lb. per sq. in. explosive pressure. Each case communicates through an 8-in. pipe from its top with a special drain for free vent in case of accident, as proposed before the INSTITUTE some time ago; but here the supply is cold oil instead of water as then proposed. With these precautions it is believed that the transformers have been surrounded with an environment unprecedented as to safety.

The power from each generator is conducted to its switch through three single-conductor braided cables carried by line insulators and isolated by shelf barriers in a subway beneath the floor. From the switches the three conductors pass to a bell chamber where between individual barriers they are united into two parallel three-conductor lead-covered and armored



FRONT, REAR AND SECTION OF BUS-BAR STRUCTURE AND SWITCHES.

cables before entering the tile ducts of the cable tunnel. Around the few bends at manholes each cable remains always within its compartment, between horizontal or vertical barriers as required. At each point where a circuit enters the distributing station, a manhole maintaining the same segregation and communicating with the bus-bar chamber is provided for the change from three-conductor to single-conductor cable. After entering the building the cables pass between vertical barriers as before beneath and through the floor to the switches above.

Bus-bar structures are composed entirely of concrete with mortised reinforced-concrete shelf-barriers between bus-bars. Connecting leads pass through the wall forming the center of the structure, and thence in compartments formed by vertical barriers of the same material, directly up to the switches above. Instrument transformers are also installed within similar individual compartments and these whole structures like those of the switches are closed by fireproof doors. Control cables are laid in metal conduit throughout their courses except in the wiring chamber beneath the track where they are arranged upon metal shelf-pans filled with dry sand into which connecting conduits dip.

Of the features here presented, it is believed that the type of intake, the symmetry of arrangement, centralization of control, and almost perfect isolation of apparatus represent, to some degree at least, distinct advances in power-plant design; and while few works of such dimensions may be built for many years, if ever, the purposes and methods thus briefly presented may, until superseded by the next advance, be of service as suggestions to other designing engineers of similar works. The unusual, even enormous volumes, both of water and of power, involved not only in the

individual units but also in the aggregate, have presented new problems heretofore unprovided-for in standard sizes of apparatus, thus necessitating the development of larger capacities and the creation of new types. Hence the work of designing and building has been burdened with incessant test, re-design and adaptation unknown in more conventional engineering. Therefore, it is believed that upon no similar work in this country, since that of the Niagara Falls Power Company years ago in the infancy of electrical power, has devolved such a burden of investigation, invention and original design.

It has been suggested by an officer of the INSTITUTE that any account of this work would be incomplete without mention of those mainly responsible for it. Justice to all is here impossible, but a few may be named. Mr. O. B. Suhr has from the beginning been in charge of the engineer corps, and to him is largely due the harmony of design. Mr. V. G. Converse, Mr. C. H. Mitchell and Mr. J. B. Bailey are chiefs of the electrical, mechanical and field departments respectively and Mr. J. R. Harsch of the clerical work of the engineers. But more than all else in the establishment of this great and daring enterprise stands out the attitude maintained toward their engineers by Messrs. J. J. Albright and Edmund Hayes, the originators and majority owners, who, in strong contrast with the harassing interference by which uninformed investors frequently spoil the best efforts of engineers, have in this case given not only absolute freedom of action but also steadfast support.